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WITH ABSTRACT OF THE LITERATURE

Editor, United States
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Chronic Poisoning by Oxalic Acid with a Report of a Case

Asphyxia from an Unexpected Cause

Carbon Monoxide Survey in Liberty Tubes, Pittsburgh

Modified Form of the Greenburg-Smith Impinger for Field Use with a Study of its Operating Characteristics

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THE JOURNAL OF INDUSTRIAL HYGIENE

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CHRONIC POISONING BY OXALIC ACID: WITH REPORT OF A CASE AND RESULTS OF A STUDY CONCERNING THE VOLATILIZATION OF OXALIC ACID FROM AQUEOUS SOLUTION*

CHARLES D. HOWARD

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THE literature on oxalic acid poisoning as contained in the standard works on toxicology is confined almost wholly to records of acute cases; such authorities as mention the chronic phase make only meager reference to it. As summing up the experience with regard to oxalic acid poisoning as recorded in the existent texts, the statement of Thompson (1, p. 421) that "industrial poisoning from this substance is very rarely encountered" is typical. Kober and Hayhurst (2, p. 658) similarly dismiss the subject with the statement that "industrial poisonings by oxalic acid are exceedingly rare." They allude to, as having been reported, but do not describe, cases of oxalic acid poisoning contracted during the polishing of brass and copper (2, p. 326). Such well-known authorities as Hamilton (3) in this country and Hope (4) in England make no reference to this subject.

A suit for recovery of damages for personal injury alleged to have been due to chronic poisoning by oxalic acid, which was recently tried in Rockingham County, New Hampshire, and which resulted in a verdict for the plaintiff, should prove of interest to those concerned with occupational ailments. During the fall of 1929 the plaintiff in the case, a married man, then aged 53, employed by a concern engaged in automobile specialty repair work, was set to work on a new process of cleansing radiators. Until recently the only treatment called for was flushing out with water, occasionally with the use of sal soda, the engine being run for a short time after the addition of this alkali. With the advent of the modern high-compression motor a more drastic form of treatment is required, and a process has come into vogue which neces-

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sitates removing the radiator from the car and boiling it out over a fire, for from one and one-half to two hours, with a strong solution of oxalic acid. In the process the operator introduced "1 or more scoopfuls" of the oxalic crystals through the radiator filler opening, his practice being to push the crystals from the scoop with his bare fingers. His hands therefore were frequently in contact with the poison, and consequently there was abundant opportunity for conveying it to the mucous membranes of the nose and mouth.

The quantity of oxalic crystals used, according to the statement of the worker, was quite variable, being never less than a scoopful (about a pint) for the smallest sized radiator (12 quarts); in many instances, depending on the size and the condition of the radiator, 2, and sometimes 3 scoopfuls were added. This would correspond roughly to a concentration of from 10 to 20 per cent. As the boiling progressed, however, the concentration increased, the point of interest here being that the greater the concentration, the more rapid is the evolution of the oxalic acid vapors. From the size of the gas flames as observed by the writer on two different occasions, it would appear that the heat applied was ample to cause active boiling at any concentration.

During the winter and up to the early spring of 1930 this operation was carried out in a room which, although of generous size and high posted, was rather poorly ventilated, no provision whatsoever being made for carrying off the steam and other vapors evolved. It was testified that at times the vapors caused a thick hazy atmosphere, which was so irritating to breathe that casual visitors to the room refused to remain, and there was complaint of these vapors penetrating to the workroom above.

The operator testified that he was wholly unaware that the chemical he was using was poisonous, and that he thought it was something like Epsom salts, or some similar innocent substance. He declared that he saw no cautionary labeling on the 100-pound kegs or boxes from which he drew, although the shop foreman testified that there was such labeling—from the first, he thought; and two labels from more recent shipments were submitted in evidence. The latter, comparatively small paper stickers, bore the name of the chemical, with the word *Poison*, and also a statement of the antidote; but the foreman admitted in his testimony that he himself had never read this statement. This is illuminating as illustrative of the degree of attention likely to be given by the average person to statements on labels, particularly when the marking is inconspicuous, or, as also in this case, when the container is stored in a dark corner in conjunction with a number of packages of other materials.

Subsequently the business was transferred to another location, but before this occurred the operator had become decidedly unwell, and there can be little doubt that a serious condition of chronic poisoning had already become established. The new workroom was smaller and much lower posted, and the windows were seldom, if ever, raised. The man's condition becoming worse, a hole was cut in the ceiling over the burners and a 15-inch fan was installed. Although this un-

doubtedly helped matters very much, because of the intervening distance of some 4 feet between the radiator tops and the fan in the ceiling the improvement is to be deemed as far from completely adequate, considering the poisonous nature of the fumes evolved and their exposure to cross air currents. Condensed vapors, in the form of a white, acid tasting deposit of oxalic acid upon the ceiling and fan blades, were plainly discernible.

By this time, however, the damage apparently had been done. The man was obliged to quit work late in May, 1930, and shortly afterward became completely disabled; from then on, he was for a long time confined to his bed, and suffered a great deal. At the present time, nearly a year and a half later, he claims to be unable to perform any sustained labor; merely climbing stairs fatigues him. Until recently he has been obliged to use a cane. His facial expression is that of a man who has undergone suffering. Prior to engaging in this operation he was said to have been an exceptionally healthy man, strong and rugged. There was no history of the use of alcohol.

According to the testimony of the plaintiff, which was corroborated by that of other witnesses, the initial symptoms involved frequent nosebleed, excruciating headaches, and repeated spells of vomiting that could not be accounted for on the basis of any digestive upsets. This condition persisted for several weeks, continuing for a considerable period after the man ceased working. The headaches were shortly followed by development of severe and constant pain in the small of the back. There was rapid loss of weight. Coughing resulted in raising bits of what appeared to be shreds of membranous tissue.

About the first of July the nosebleeding ceased, although sneezing or exertion tended to cause recurrences. By this time the man complained that he was scarcely able to move; for a while he was unable to get out of bed or to raise himself in bed, and he had to be fed. As he testified, "I seemed to be paralyzed from the waist down; legs did not seem to be there at all. A little noise would just about set me crazy."

This condition of extreme nervousness and loss of motion in the limbs was borne out by the testimony of attendants, who stated that the man would "scream if the bed was touched," and that later, when able to move about a little, he could reach the toilet only by going on hands and knees. While he was in bed, the knees had to be supported to gain any relief from the pain. There was complaint of being cold, and blanket covering was almost constantly required during July and August.

From May on, the victim was seen and treated by no less than five physicians, all of whom diagnosed his ailment as some form of industrial disease; the three who gave testimony were agreed that his condition was consistent with oxalic acid poisoning. One of the three physicians who saw him prior to his confinement to bed, testified that he complained of severe and almost continuous headache, with frequent bleeding from the nose, and of periods of nausea. This physician noted that there was an ulcer on the nasal septum, and that the mucous membranes of both nostrils were highly congested, and the small blood

vessels engorged; this condition extended into the back of the throat and as far down as could be observed. The urine was tested for albumin and was found to have a high content; otherwise it was not specially examined.

The second physician to testify, and who gave bedside treatment, stated that on his first visit, before entering the house he heard the plaintiff moaning; he found him very anemic, with a bronchial cough. At that time he saw nothing in the nose or mouth suggestive of erosion, but the nasal membranes showed considerable inflammation. The position of the patient in bed was one self-acquired to relieve pain. Drawing the hips down to the foot, he would flex his knees over the footboard, and in this way apparently obtained some relief. In this physician's opinion, the restricted motion was due to pain and stiffness generally throughout the body; his examination showed the reflexes to be normal. There was no swelling of the muscles or joints, and no special tenderness on manipulation. The lungs and the heart action were normal. The teeth were fairly good, with no sign of metallic poisoning around the margin of the gums. The tonsils were not infected; voice was normal. No enlarged cervical or inguinal glands were observed. His skin was pallid and dry; "without doubt had marked secondary anemia." Treatment consisted in one-half grain codeine freely administered to relieve pain. Potassium iodide and salicylates were incorporated as routine treatment.

The third physician giving testimony, and who saw the patient from late July into September, found him in a condition of extreme exhaustion and still complaining of a great deal of pain in the lower back and limbs. At that time there was weakened heart action and lack of normal use and control of the extremities. Sedatives constituted the only treatment, with instructions to avoid exertion.

It is unfortunate, perhaps, that none of the five attending physicians apparently made any special clinical or laboratory study or corroborative investigation, such as might have thrown more light on the identity of the toxic agency responsible. Nevertheless, this case is instructive because, as was pointed out, the literature contains so little bearing on the manifestations of chronic oxalic acid poisoning. All the cases recorded have involved the swallowing of a solution of the drug. Not infrequently the action is extremely rapid, one case on record resulting in death in as short a time as three minutes. When swallowed, oxalic acid acts both as a corrosive and as a true poison (systemic). The corrosive effect involves softening and loosening of the lining membranes of the mouth and esophagus, with vomiting—usually bloody or dark colored—intense burning pain, collapse, and sometimes convulsions, the case rapidly terminating in death if the dose has been large, or if proper treatment has been lacking. The poisonous action, according to authorities hereinafter cited, is due largely to the avidity of the oxalic acid for the base, calcium. Calcium is abstracted from the blood, with reduction in the alkalinity, increase in the sugar content, and weakened heart action; ultimately the nervous system is affected. The kidney tubules become obstructed by the insoluble calcium oxalate taken up from the blood,

and there is profound renal disturbance. Most of the ingested poison not retained in the circulation or deposited in the organs is eventually excreted in the urine as insoluble calcium oxalate.

As bearing on the chronic manifestations, the following has been gleaned from some of the better known American and English authorities on toxicology:

Blyth (5, p. 548) states that "certain nervous and other sequelae are more or less constant, always time being given for their development." Referring to the pathology, this authority has observed that if the poisoning lasts a long time, "the kidneys become less blood-rich, and show the described white striping very beautifully; this change persists several weeks. The cause of this strange appearance is at once revealed by a microscopical examination; it is due to a deposition of oxalate of lime. . . . . Both by the microscope and by chemical means it may be shown that the content of the kidney in oxalates is large. . . . . The urine was always albuminous and contained a reducing substance, which vanished about the second day after the dose. Hyaline casts and deposits of oxalates in the urine never failed."

Allen (6, p. 700) states that the oxalic acid extracted from the stomach and intestines is chiefly uncombined, but that that obtained from the liver, kidneys, heart, and urine is wholly in combination.

According to Autenrieth (7), "the effects caused by oxalic acid may be ascribed to the fact that this acid removes in part from the organs, as the heart, and from the body fluids (blood) calcium they require for their life processes, converting it in part into insoluble calcium oxalate. Oxalates diminish coagulating powers as well as alkalinity of the blood. On the other hand, they increase the quantity of sugar in the blood. Owing to the withdrawal of calcium from the heart that organ is weakened and finally paralyzed. Local action upon the kidneys is due to clogging of the injured urinary tubules by deposits of calcium oxalate. A striking thing about the urine excreted during oxalic acid poisoning is the abundant deposition of crystallized calcium oxalate."

Amory and Emerson (8) observe that oxalic acid "produces a disturbance of the respiration, and enfeebles the action of the heart, and makes its contractions irregular (arrhythmic); it also causes nervous symptoms, as shown by spasms and muscular languor." They refer to experiments performed on dogs by Kobert and Küssner, who reported that "the first symptom of poisoning, observed in both subacute and chronic forms, was a soporific condition and the reflex action weakened. The muscular action of the hind legs was also weak, and gradually deepened into a complete paralysis. This paralytic condition gradually extended into the fore legs. On the sixth day the hind legs lost the reflex action and were motionless."

Taylor (9, p. 226) describes a case of chronic character in which during the first month there was numbness, with tingling of the legs, and loss of voice. "The occurrence of this sensation of numbness, and its persistence for so long a period after recovery from the symptoms of irritation, clearly point to a remote effect on the spinal nervous system. Spasmodic twitchings of the muscles of the face and extremities

have also been observed in some instances."

Holland (10, p. 138) also mentions numbness and tingling in the extremities, with loss of voice. "When a small dose has been taken in dilute solution, the symptoms have not come on for hours, and then the nervous phenomena are more prominent." Thompson (1, p. 420) states that oxalic acid disorganizes the blood, destroying the red cells.

But one authority, Blyth (5, p. 545), refers to the effects of the inhalation of vapor, as involved in the case here discussed. He describes some experimental work of Eulenberg's in which pigeons were exposed for a few minutes to the vapors evolved in a glass case. Death resulted the sixth day following such exposure. "Examination after death showed slight injection of the cerebral membranes; the cellular tissue in the neighborhood of the trachea contained in certain places extravasations of blood, varying from the size of a pea to that of a penny; the mucous membrane of the larynx and trachea was swollen and covered with a thick croupous layer; the lungs were partially hepatised, and the pleura thickened."

The external manifestations of ingestion of oxalic acid are said to include an opalescent or bluish discoloration of the nails, with brittleness, and blood stasis in the hands. External contact with this poison in strong solution results in a similar effect on the nails, and, as might be expected, there is some corrosive action on the skin. In the case here described the victim handled the dry acid freely but claimed to have experienced no troublesome effects on his hands. Much of the time, however, he wore heavy gloves, because of the frequent handling of the hot radiators. Presumably, in the course of time his working garments must have become more or less impregnated with the vapors.

Oxalic acid is rather widely distributed in minute quantities in nature. Its presence in rhubarb and sorrel as oxalate has long been known, and more recently its presence has been reported in such foods as spinach, currants, sugar cane, and cocoa. The urine normally carries small quantities, always as oxalate and commonly as the calcium salt. Commercially, oxalic acid is prepared on a large scale by the action of caustic alkali on cellulose material (sawdust), but there are now other processes of synthesis not based on organic origin. This acid has long been recognized as an efficient cleanser for metals; it is very effective for the removal of tarnish on copper, brass, and aluminium.

Oxalic acid sublimes readily when heated to 150°. The optimum temperature is placed at 157°; decomposition into carbon dioxide, carbon monoxide, and formic acid occur at 160° and above. Although it is well known that the dry acid volatilizes sensibly at the temperature of boiling water, the literature is rather strangely silent as to the behavior in this respect in aqueous solution. Allen (6), however, states that saturated solutions lose acid at 100°. Blyth (5, p. 542) also refers to this fact, stating that "an aqueous solution, if kept at 100°, loses acid; hence all evaporating or heating operations must not exceed 98°, or there will be some loss."

That such a solution at the boiling

temperature does evolve this acid in substantial degree was confirmed by the writer. Thus, on rapidly boiling 100 c.c. of a 10 per cent. solution in a 500-c.c. Kjeldahl flask fitted with the usual trapped-bulb distilling tube, very appreciable quantities of the acid are volatilized, as determined by titration with alkali and by conducting into silver nitrate solution. The rate of evolution is governed by the rate of boiling, but concentration is also a factor. When the latter exceeds 20 per cent. the evolution is rapid; with still further concentration white vapors of oxalic acid are to be noted in the condenser tube, while on cooling, the distilling tube will be found to contain a mass of crystals. If some copper foil is added, the rate of evolution is about doubled, while boiling in contact with aluminium foil increases the volatilization nearly fourfold.

It is, however, a notable fact that if the boiling is conducted in a copper flask instead of in glass, the rate of vaporization is much diminished for the same degree of heating, owing presumably to the great heat conductivity of the copper. It was also found that that when the heating is effected by passing a current of steam through the solution, the degree of acid volatilization is, comparatively, very slight.

When a solution of oxalic acid is boiled with aluminium foil a gas is evolved, carrying vapors which are decidedly irritating to inhale. With concentrated solutions, traces of formic acid are apparently generated. If this operation is conducted under a reflux condenser and the gas led through an ammoniacal solution of calcium chloride, an evolution of hydrogen will be noted, and after some hours small quantities of carbon dioxide will be found to have come over. With copper foil there is no hydrogen liberation whatsoever, and only minute quantities of carbon dioxide are generated. In both instances the carbon dioxide may result from a breaking down of formic acid. However, the generation of any appreciable quantities of this acid failed to be demonstrated.

Finally, when a moist film of oxalic acid is exposed to the temperature of boiling water on the ring of a copper water bath, the hole in which is nearly closed, and a cold glass surface is superimposed, white vapors of oxalic acid can be distinguished, depositing as a film upon the glass. We have a situation comparable to this afforded by the brass bottom of the upper tank of an automobile radiator, after the acid solution has boiled down to this level. The numerous small copper tubes in the radiator also doubtless favor volatilization of this acid as the concentration increases.

One of the conditions alleged by the operator in the case here cited was the discharge into the workroom at times of a white "smoke." This might be expected to result when the radiator contents became substantially concentrated, as it is altogether likely occurred at times, in view of the protracted boiling periods employed.

BIBLIOGRAPHY

1. Thompson, W. G.: The Occupational Diseases. Their Causation, Symptoms, Treatment and Prevention. New York and London, D. Appleton & Co., 1914.
2. Kober, G. M., and Hayhurst, E. R.: Industrial Health. Philadelphia, P. Blakiston's Son & Co., 1924.
3. Hamilton, A.: Industrial Poisons in the United States. New York, The Macmillan Co., 1925.
4. Hope, E. W., Hanna, W., and Stallybrass, C. O.: Industrial Hygiene and Medicine. New York, William Wood & Co., 1923.
5. Blyth, A. W., and Blyth, M. W.: Poisons: Their Effects and Detection. Fifth edition. London, Charles Griffin & Co., 1920.
6. Allen's Commercial Organic Analysis. Fifth edition. Philadelphia, P. Blakiston's Son & Co., 1923, vol. 1.
7. Autenrieth, W.: Laboratory Manual for the Detection of Poisons and Powerful Drugs. Sixth edition, translated by W. H. Warren. Philadelphia, P. Blakiston's Son & Co., 1928.
8. Amory, R., and Emerson, R. L.: Wharton and Stillé's Medical Jurisprudence. Fifth edition. Rochester, Lawyers' Co-operative Publishing Co., 1905, vol. 2.
9. Taylor, A. S.: On Poisons in Relation to Medical Jurisprudence. Third American edition. Philadelphia, Henry C. Lea; London, J. & A. Churchill, 1875.
10. Holland, J. W.: Inorganic Poisons. Legal Medicine and Toxicology, by F. Peterson, W. S. Haines, and R. W. Webster. Second edition. Philadelphia and London, W. B. Saunders Co., 1923, vol. 2.

J. I. H.
Oct., 1932

ASPHYXIA FROM AN UNEXPECTED CAUSE*

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H. M. Medical Inspector of Factories

FIVE men met their death in an open caisson while engaged in excavating near the bed of the river Thames. The occurrence was so unexpected that it has been considered advisable to place on record the circumstances of the accident.

The site was that of a large new factory in the course of erection, and in the preparation of the foundations to receive the heavier structures, many caissons had been used successfully and without the occurrence of any accident similar to that met with in the present instance.

The caisson in which the accident happened was a cylinder of steel plate, 14 feet, 6 inches in diameter, and the working surface was about 30 feet below ground level at the time. The lowest section of the caisson was provided with a cutting edge so that the cylinder would sink as the soil inside was excavated. The working chamber was 8 feet high and had a conical steel roof which was entered through a figure-of-eight shaped smaller cylinder, arranged so as to provide separate air locking compartments for men and material. At the time of the accident, however, the air lock had not been applied and the working chamber remained open to atmosphere through the figure-of-eight cylinder and the caisson cylinder. Electric light was used for night work.

The ground through which the caisson passed consisted of approximately 30 feet of soil, which was composed, from above downward, as follows: made-up ground, 12 feet; light or muddy clay, 13 feet; brown peat, 4 feet; muddy clay, 2 feet. At the time of the accident the cutting edge of the cylinder was in this layer of muddy clay, and immediately below lay the water bearing ballast. The ground level was 16 feet above the ordnance datum line.

The accident occurred at 5 o'clock on the morning of Saturday, July 25, 1931. The presence of "gas" was first reported to the day shift foreman at 5:15 P.M. on Friday, and on entering the working chamber he found foul-smelling air which seemed to come from the ground. He sent the men to the surface and put a $\frac{3}{4}$-inch air line to the chamber with air at a pressure of 100 pounds to the square inch, and reported to the resident engineer. The night shift men came on duty at 6:45 P.M. At 8 o'clock examination showed the air of the chamber to be good, and the air supply was maintained, though partly throttled down on account of the noise it produced in the chamber. The men resumed digging, with the object of bringing the cylinder into the vertical position

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before it reached the ballast layer. At this time the excavated material was peat; the ballast layer had not been reached but was thought to be near.

By arrangement, the night shift foreman reported at 2 A.M. to the resident engineer. His report was to the effect that the cylinder was nearly in the vertical position and that there was no water in the bottom. The engineer instructed him that if water came in, he was to stop work and report at once. It is certain, however, that water had appeared in the bottom soon after the resident engineer left the working at 11 P.M., and the night shift foreman had brought a pump and, using the air line to work it, had attempted to pump the water out. Owing to failure of the pump after half an hour's operation, work in the bottom was stopped for a time and the men came out of the working chamber. At 3 A.M. the pump was again tried, but unsuccessfully.

At 5 A.M. the foreman asked the men to try the pump again. M. went down into the working chamber and was seen to collapse almost immediately. J. gave the alarm and quickly descended, followed by K., P., and the foreman O. who, in passing another man, sent him for assistance. When help arrived after not longer than one or two minutes, the five men could be seen lying on the bottom apparently dead. A diver and a fireman, wearing breathing apparatus, raised the men to the surface, but life was found to be extinct.

Postmortem examinations were made on the afternoon of Monday, July 27. All the deceased were well-developed, muscular men and their ages ranged from 22 to 30 years. Bruises were seen on the body of M., one on each leg just below the patella, on the left arm at the insertion of the deltoid muscle, and on the scalp over the left anterior vertex. These injuries were superficial. In no other case was there any evidence of external injury.

In all cases there was extensive postmortem lividity which was most marked in the case of K., the youngest of the men. The lips were dark. In the cases of J. and M. only, there was froth in the mouth. In all cases the muscles were of a dark red color. The pleural cavities contained straw-colored fluid which varied in amount from a trace to a considerable quantity. The lungs were dark red in color and were engorged over nearly their whole extent. In most cases there was some distension of air vesicles in parts, giving the appearance of emphysema. In every case the lungs floated on water and there was no evidence of drowning. On section the lungs were seen to be engorged with very dark red blood, which did not suggest the presence of carbon monoxide, and there was no unusual odor.

The pericardium in most cases contained some free fluid. The heart in each case showed muscle and valves sound; the left ventricle was empty except in the case of M., when it contained dark blood and clot; the right ventricle in each case contained dark blood and clot.

The stomach contained, in each case, a quantity of partly digested food; the mucous membrane was engorged; there was no sign of poisoning and no unusual odor. The liver was enlarged and, like the kidneys and spleen, was engorged with blood in each case.

The signs were those of asphyxia,

with slight variations, depending, it appeared, on the individual reactions toward the atmosphere and the conditions of exertion and exposure.

A sample of air was taken fifteen hours after the accident at a point within the working chamber, just above the surface of the water. Analysis of the sample showed the composition to be as follows: carbon dioxide 14.36 per cent.; oxygen 0.12 per cent.; methane 4.59 per cent.; nitrogen (by difference) 80.93 per cent.

It is somewhat difficult to account for the almost complete absence of oxygen from the air, but the unusual conditions prevailing in the vicinity at the time may offer an explanation. It will be remembered that the cutting edge of the caisson cylinder was, at the time of the accident, in a layer of clay 2 feet thick, above which was a layer of peat, while below it was the water bearing ballast. Not far from the site is the river Thames, and opposite this point the bed of the river is formed by 10 feet of river mud, below which is sandy ballast. In the vicinity of the caisson in which the accident occurred a number of caissons were working under compressed air, and it was noted that at many points nearby, air under pressure was forced to the surface of the ground.

In view of these facts it seems reasonable to infer that what happened on this occasion was as follows. The water bearing layer of ballast was the stratum into which air under pressure had escaped from a number of caissons, and this air passed through the strata at points of least resistance. In the caisson in which the accident occurred, the air in the ballast layer was kept down by the layer of clay until this became so reduced in thickness that it failed to resist the upward pressure of air. Escape of air from the ballast layer occurred into the working chamber which had no counterpressure to offer, and with it some water which would help perhaps to increase the opening. On the afternoon following the accident the water could be seen in a continuous state of agitation from the large volume of air bubbling upward through it, and it was air from this source which was sampled. It must be inferred that the air under pressure from the neighboring caissons was altered in composition in percolating through the ballast layer which was probably saturated with water containing organic matter in solution and suspension.

The accident resulted from a number of unfortunate circumstances. If the entry of water had been reported immediately or if it had occurred during the daytime, the air locks would have been fitted and compressed air applied before anyone could be injured. The air line which had been used to supply the working chamber in the early part of the night was capable of providing a complete change of air in the chamber in eight minutes. If this air supply had been maintained it would have been sufficient to insure safety of life; or, if the pump which it was used to drive had functioned properly, the exhaust air would have been sufficient for the purpose.

As it happened, the atmosphere to which these men exposed themselves was incapable of supporting life. The first man to enter, M., evidently realized his danger and attempted to shout a warning, but fell insensible; the others followed unhesitatingly to res-

cue, and lost consciousness immediately on entering the chamber.

Such accidents are, fortunately, of rare occurrence, but from time to time lives are lost through persons entering a deep well or other excavation in which the oxygen has become rarefied so as to be insufficient to support life. The only safe rule for such work must be that if there is any likelihood of the atmosphere in an unventilated enclosure being incapable of supporting respiration, no person may enter until the air has been tested.

If tests with a miners' lamp or with a small animal indicate that the atmosphere is dangerous, adequate air supply should be established and maintained by mechanical means, and the workers should be provided with life lines so that they can be hauled up if necessary. Alternatively, any person entering the dangerous atmosphere should wear a breathing apparatus, which renders him independent of the atmosphere of the place, and a life belt with a rope attached, the free end of which should be in charge of a man whose sole duty it is to keep watch and to draw out the wearer if he appears to be affected by the atmospheric conditions to which he is exposed.

Summary

The conditions are described under which five men, employed upon caisson work, lost their lives.

An unusual combination of circumstances led to air which had become deoxygenated by passage through organic matter in solution and suspension, gaining access to the working chamber of a caisson.

This air was found to contain 14.36 per cent. of carbon dioxide and only 0.12 per cent. oxygen.

Valuable assistance received from colleagues in the preparation of this memorandum is gratefully acknowledged.

CARBON MONOXIDE SURVEY IN LIBERTY TUBES, PITTSBURGH*

CARBON MONOXIDE SURVEY COMMITTEE, PITTSBURGH, PA.[1]

C. B. MAITS, CHAIRMAN

DURING the twelve months beginning July, 1931, a study was made in Pittsburgh to determine concentrations of carbon monoxide from automobile exhausts. Among the stations at which continuous records were made were prominent street corners, public parking garages, and a vehicular tunnel. The apparatus used was furnished by the U. S. Bureau of Mines and is described in the Bureau's Technical Paper No. 355.

While the survey report is not yet completed, a preliminary report was made to the Commissioners of Allegheny County, at their request, covering the findings in the Liberty vehicular tunnel, which connects the downtown business district with the South Hills residential district.

The twin parallel tubes are 33 feet apart and 5,888 feet long, with a cross-sectional area of 468 square feet each. In each tube there is a roadway 21 feet wide, flanked by two sidewalks, each $2\frac{1}{2}$ feet wide. Between the tubes are small crossover passageways at approximately 500-foot intervals.

The ventilating system consists of eight Sirocco-type fans, in a fan-house located directly over the tunnel and slightly south of the midpoint. Each tube may be considered as divided into two sections, the contaminated air from the entrance to the midpoint of each being exhausted through a shaft and discharged through a stack 100 feet high; fresh air is forced through another shaft to supply the tube from the midpoint to the exit.

The following transcript of the communication from the survey committee to the county commissioners reports upon the carbon monoxide concentrations found and makes some recommendations intended to minimize danger from this source.

A committee composed of representatives from the U. S. Bureau of Mines, Mellon Institute of Industrial

* From a report of June 4, 1932 to the Chairman and Members of Board of Commissioners of Allegheny County, Pa.

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DATE	MORNING PEAK	MORNING AVERAGE	LATE AFTERNOON PEAK	AFTERNOON AND EVENING AVERAGE
Apr. 9	160 (noon)	100	145	90
10	115 "	75	160	100
11	140	70	220	70
12	105	55	185	60
13	95	50	180	65
14	95	60	180	70
15	85	70	185	80
16	140 (noon)	95	185	85
17	32	45	420 (jam)	90
18	146	65	195	70
19	100	70	215	80
20	100	65	212	100
21	130	80	207	90
22	200	75	210	100
23	135 (noon)	80	131	100
24	115 "	45	170	110
25	200	75	240	85
26	145	75	145	75
27	105	70	210	85
28	105	75	210	90
29	105	75	205	90
30	120		200 (noon)	110
May 1	50	40	175	95
2	167	70	345	80
3	95	70	332	80
4	95	75	315	95
5	134	80	315	110
6	130	90	270	105
7	135	100	175	125
8	170 (noon)	105	164	130
9	120	100	490	85 (jam or power off)
10	180	80	200	80
11				
12	165	80	180	65 special test 4:30–6:30
13	95	80	230	95 " "
14				95
15	150 (noon)	75	170	145
16	95	90		95
17		65	215	80
18	135	80	360	90
19	175	80	255	90
20	110	80	235	90
21	130	85	190 (night)	90
22	105	60	140	110
23	180	70	200	80
24	115	80	240	90
25	130	90	470	115
26	300	95		

J. I. H.
Oct., 1932

Research, the University of Pittsburgh, the U. S. Weather Bureau, and the Departments of Health and Safety of the City of Pittsburgh, have been engaged in a study to determine concentrations of carbon monoxide at busy traffic points in the City.

Inhaled carbon monoxide combines with the hemoglobin of the red blood cells, thereby displacing a certain amount of oxygen and depriving the body tissues of normal oxygen supply. As a result, there is tissue asphyxiation, in degree depending upon the extent of the oxygen deficiency and its duration. The extent of oxygen deficiency is dependent upon the degree of concentration of the carbon monoxide. Early symptoms of acute carbon monoxide poisoning may be yawning, sleepiness, lassitude, headache, dizziness and nausea. Recovery from such cases of exposure to comparatively low concentrations follows upon removal to pure air.

As a part of the investigation in the City, it was desired to secure information concerning the concentration of carbon monoxide in the Liberty Tubes. The County Commissioners offered their co-operation, and the apparatus was set up in the fan house and continuous samples of air from the uptake section of the southbound tube were analyzed during the period from April 8th to May 26th, 1932. Following is a very brief summary of the results:

The normal operating speeds of the ventilating fans are 50 revolutions per minute on the exhaust side and 75 revolutions per minute on the supply side of each tube. These speeds are not changed except upon request from the traffic officer stationed at the mouth of the tunnel, and upon very warm days.

DATE	TIME	TOTAL CARS PER HOUR	AV. CO (P.P.M. PER HOUR)
Apr. 9	10–11	622	70.6
	11–12	702	79.0
	12–1	1107	133.8
	1–2	1398	111.4
	2–3	386	103.0
	3–4	1230	101.4
	4–5	1302	107.0
	5–6	1319	107.8
Weather—warm; rain			
Apr. 11	9–10	622	68.0
	10–11	564	70.6
	11–12	697	68.6
	12–1	628	69.4
	1–2	51	70.3
	2–3	761	70.8
	3–4	888	75.6
	4–5	1302	103.0
	5–6	1337	168.0
Weather—cloudy; rain			
Apr. 12	9–10	647	49.3
	10–11	550	45.9
	11–12	581	45.9
	12–1	597	45.6
	1–2	196	46.5
	2–3	669	54.3
	3–4	1845	54.3
	4–5	981	66.6
	5–6	1524	116.5
Weather—cold; snow			
Apr. 13	9–10	555	38.4
	10–11	536	43.7
	11–12	613	42.6
	12–1	339	41.4
	1–2	688	47.0
	2–3	684	52.1
	3–4	713	50.4
	4–5	1272	65.2
	5–6	2211	108.6
Weather—cold; snow			
Apr. 14	9–10	793	53.2
	10–11	777	55.2
	11–12	929	55.4
	12–1	309	47.0
	1–2	738	49.8
	2–3	705	60.5
	3–4	912	59.9
	4–5	1511	73.4
	5–6	1378	122.1
Weather—clear; cold			

The tabulation on page 296 shows the concentration of carbon monoxide, in parts per million, in the air exhausted through the fan. Averages are given for the morning peaks, approximate morning averages, late afternoon peaks, and approximate afternoon and evening averages.

DATE	TIME	NO. OF CARS	FAN SPEEDS	CARBON MONOXIDE	
				MAX.	AV. (APPROX.)
Apr. 13	5:00–6:00 PM	2211	50–75	175	115
14	5:00–6:00 "	1379	50–75	170	125
May 12	5:00–6:00 PM	2307	100–145	180	145
13	5:00–6:00 "	2418	100–145 (4:30–5:20) 115–175 (5:20–6:30)	230	165

DATE	TIME	NO. OF CARS	FAN SPEEDS	CARBON MONOXIDE	
				MAX.	AV. (APPROX.)
May 20	5:20–6:05 PM	2039	50–75	220	180
23	5:00–6:00 "	2519	50–75	200	160
25	5:15–5:45 "	1228	50–75	270	210

Traffic was counted during five days (April 9th, and April 11th to 14th). The results are given in the table on page 297.

It was decided to ascertain the effect of increased fan speeds upon the concentration of carbon monoxide during the peak hours. The superintendent of the tunnels was very willing to co-operate, but stated that possibly he did not have authority to increase the speeds to the extent that might be desired. This was because the maximum limit of speed was fixed in the instructions given him; and, due to the method of billing by the electric light and power company, he feared an increase in cost, based upon the power peak. The afternoons of May 12th and 13th were selected for the experiment, and the Duquesne Light Company agreed to ignore the power peak during those periods, so that any expense for additional current used was borne by them and not by the County. The results are as tabulated above.

Additional traffic counts were made during the afternoon peak periods on May 20th, 23rd and 25th.

On May 19th, 20th and 25th, readings were taken inside the tube with a portable carbon monoxide indicator, which was held at approximately breathing level. Because the calibration of this meter varies with the concentration of carbon monoxide, absolute comparisons with the recorder in the fan house are not made here. However, concentrations as

read during peak hours of traffic varied from 100 to 640 parts per million.

The data collected show:

1. That the highest traffic count for a five minute period was 284, which, if maintained, would be at the rate of 3400 cars per hour. A report by Fieldner, Yant and Satler (Engineering News Record, August 21, 1924) stated that 300 to 500 cars per hour was not often exceeded, and the highest count showed 1200 cars per hour.

2. That, during peak periods, brief stoppages of traffic, jams, were frequent.

3. That the concentration of carbon monoxide during periods often exceeded a desirable maximum. Such concentration, if breathed for an appreciable length of time, would produce definite symptoms of carbon monoxide poisoning.

4. That increasing the fan speeds did not result in as great a decrease in concentration of carbon monoxide as was expected.

When the County Commissioners granted permission to make this study in the Liberty Tubes, as a part of the survey mentioned previously, they asked that the committee forward any suggestions that occurred, which might improve conditions.

Recommendations

Following the completion of this preliminary study and the consideration of the findings by the members of the Committee, the following recommendations are offered respecting the operation of the ventilating system in the tunnel, and particularly respecting the control of traffic.

1. A desirable minimum speed for cars, to be maintained passing through the tunnel during peak hours (7:00 to 9:30 AM and 4:00 to 6:30 PM, Sundays and holidays excepted), is 25 miles per hour. Vehicles (including those horsedrawn), incapable of maintaining this speed, should not be permitted to enter the tunnel during these periods.

2. Vehicles should not only enter the tunnel at 25 miles or more, but should maintain their speed throughout.

3. Crossing the white line, dividing the two lanes of traffic inside the tunnel, should be prohibited.

4. An emergency car should be maintained at each end of the tunnel. This car should be equipped with tow rope, a small crane, fire foam, an inhalator and a first-aid kit, and should be manned by persons trained in the use of these various appliances.

5. Cars should not be permitted to stop in the tunnel. In case of breakdown, signal should be sent through an appropriate alarm system to the end of the tunnel for the emergency car. For the service of this emergency car, a fee should be charged.

6. U. S. Bureau of Mines, at its Pittsburgh Station, will be glad to give instruction in the use of inhalator and in first-aid treatment of carbon monoxide poisoning cases.

7. Traffic officers, stationed at the tunnel, should also be familiar with the dangers arising from concentration of carbon monoxide and in emergency first-aid treatment of such cases.

8. Pedestrians should be prohibited from using the tunnel during peak hours. If this is considered too drastic, proper warning signs should be displayed not only at the entrances to the tunnel, but at intervals inside.

9. Steps should be taken to prevent traffic in the tunnel being either slowed up or stopped by reason of congestion at the mouth of the tunnel, due to cross traffic.

10. A more complete study might well be made, to include sampling, at different levels, from different points in each tube, to determine variations in concentration of carbon monoxide with different densities of traffic and different temperatures and relative humidities.

11. The fans should be tested, if this has not been done recently, to measure the outputs at different speeds—actually to determine the efficieney of the fans and ducts.

12. It is believed that the ventilating system should be operated according to the demand upon it, as evidenced by concentration of carbon monoxide. There should be a carbon monoxide indicator for each side of each tube. The attendants in the fan house could regulate the speeds of the appropriate fans to maintain the carbon monoxide below a certain level of concentration. Or it would be possible to have the fans increase speed automatically when a certain predetermined concentration is reached. Such a system, properly operated, will use less power than now during periods of low concentration, more during periods of high concentration. The total cost of operation, however, need be no greater, and probably would be less, than at present.

As a matter of fact, the experience at the Holland Tunnels in New York has been such that the equipment paid for itself in a short time in the saving of power cost through cutting down unnecessary current consumption during periods of low traffic.

The Committee offers to the County Commissioners its further co-operation in any part or parts of this program for which they may desire such assistance.

J. I. H.
Oct., 1932

MODIFIED FORM OF THE GREENBURG-SMITH IMPINGER FOR FIELD USE, WITH A STUDY OF ITS OPERATING CHARACTERISTICS*

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INTRODUCTION

THE Greenburg-Smith impinger was introduced in 1922 (1) and a report on its operating characteristics and dust collecting efficiency was published in 1925 as part of a comparative study of the characteristics of various instruments for determining atmospheric dusts (2). Since that time this instrument has almost entirely replaced other sampling devices in field investigation of the industrial dust hazard in the United States. The impinger possesses certain advantages which in no other method of dust sampling are combined in a single instrument. These advantages may be summarized briefly as follows:

1. High dust collecting efficiency (96 per cent. against silica dust).
2. No limitation with respect to dust concentration.
3. Simple construction and cheapness.
4. Quantitation of the sample by chemical, gravimetric, or microscopic means.

Details in the design of the instrument have been modified from time to time since it was first described. In the original instrument the impinging nozzle consisted of a glass disk sealed to the bottom of the inlet tube and pierced with fifteen holes, each approximately 0.8 mm. in diameter. The plate was located at a distance of 0.8 mm. from the bottom of the flask, which served as the impinging surface. In the 1925 report an impinging nozzle having a single hole 2.3 mm. in diameter was described. The impinging surface was provided by a bronze plate suspended from the inlet tube by means of a suitable metal clamp and located at a distance of 5 mm. from the end of the nozzle. The impinging tube and suction elbow were inserted in a two-hole rubber stopper and the apparatus was assembled in a 16-ounce bottle in which approximately 200 c.c. of water was placed. In this instrument as well as the earlier one, the sampling rate was set at 1 cubic foot per minute.

Further experience suggested other changes which have been incorporated in the instruments employed by the United States Public Health Service. This instrument, recently described by Greenburg and Bloomfield (3), employs, in place of the metal impinging plate, a glass disk suspended from the inlet tube by three glass rods; and the bulky 16-ounce bottle (or 500-c.c. Erlenmeyer flask) has been replaced by a round-bottom tube 50 mm. in diameter and 300 mm. in length. With a flask of this type, the required

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water volume is reduced from 200 c.c. to 100 c.c. The diameter of the impinging nozzle, the impinging distance, and the sampling rate remain the same as those previously adopted. For the sampling of gases, Smith and Friis (4) introduced additional changes, including a special absorption vessel in place of the impinger flask. Smith seals the impinging nozzle into the absorption vessel, which is provided with a suction connection and also an outlet at the bottom through which the collecting liquid and absorbed gas are removed.

These modifications in the design of the impinger have not in any way altered the basic principle on which the instrument operates. Their purpose has been simply to make it more compact and more convenient for field use.

Modified Impinger

In order further to simplify the impinger, to make it more compact and less subject to breakage, the design shown in Figure 1 is suggested. The flat bottom of the flask serves as the impinging surface, thereby eliminating the fragile glass plate and supporting rods, and simplifying the construction of the impinger tube. The assembly is further simplified by combining the suction connection with the inlet tube. The flask is 50 mm. in diameter and

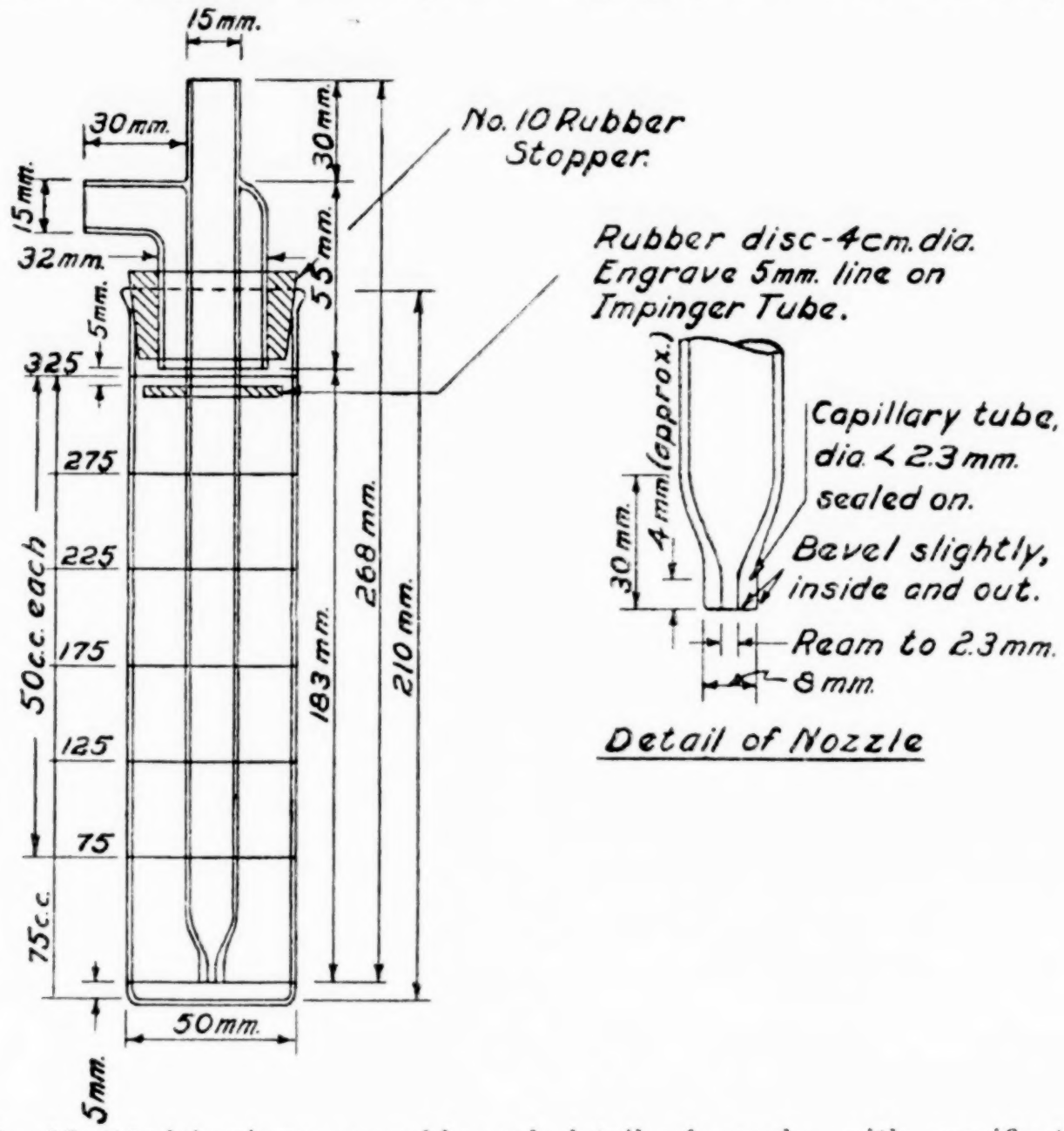


Fig. 1.—Modified impinger assembly and detail of nozzle, with specifications for construction.

210 mm. in height, and requires a water volume of only 75 c.c. to give the proper depth of immersion of the nozzle (3, p. 666). Volumetric graduation lines are provided to facilitate quantitation. In order to prevent entrainment and consequent removal of the liquid (and dust) with the outgoing air, an entrainment trap in the form of a rubber ring is provided.

The chief difference between this instrument and the standard type lies in the fact that the impinging distance is not fixed. A guide line is engraved on the flask 5 mm. from the bottom, to which the end of the nozzle can be adjusted quickly and easily. In field practice, however, a wide variation in the actual distance may be expected. Moreover, the impinging tube may not be perpendicular to the bottom of the flask, particularly since the weight of the suction hose has a tendency to throw it out of adjustment. It follows, therefore, that unless considerable tolerance is allowed in the specifications regarding the position of the nozzle in relation to the impinging plate, an instrument of this type would have little practical value.

TABLE 1.—EFFECTS OF CHANGING RATES OF FLOW AND DISTANCE OF PLATE FROM ORIFICE ON EFFICIENCY OF ADJUSTABLE IMPINGER AGAINST TOBACCO SMOKE[1]

IMPINGING DISTANCE	EFFICIENCY AT			
	20 L./Min.	25 L./Min.	28.3 L./Min.	35 L./Min.
mm.	%	%	%	%
1	5	8	9	12
2	7	10	13	20
5	8	10	20	32
10	5	10	20	34
15	5	8	15	29
20	..	..	10	19

[1] Data tabulated from (2, Fig. 14, facing p. 63).

The fixed impinging distance of 5 mm. adopted by the Bureau of Mines was determined from the results of a study of the influence of this factor on the efficiency of the impinger against tobacco smoke and silica dust. In the case of tobacco smoke, the efficiency was found to be very sensitive to the impinging distance (Table 1). The curves from which these data are taken show an optimum distance which increases with the rate of sampling, from 5 mm. for a rate of 20 liters a minute to 9 mm. at 35 liters. In the case of silica dust, on the other hand, the effect of changing the impinging distance was not marked. The efficiency dropped only 11 per cent. (from 96 to 85 per cent.) when the impinging distance was increased from 1 to 10 mm. The value 5 mm. was finally chosen for the practical reason that for distances of 3.5 mm. or less, dust was found to adhere to the plate. It is clear, therefore, that an accurate adjustment of the nozzle is not necessary. Further data were obtained in this laboratory while investigating the new instrument.

Experimental Study

Measurement of Efficiency

In the study reported in 1925, the collecting efficiency of the impinger was determined by diluting a portion of the original suspension until the concentration was equal to that in the air discharged by the instrument. Equal concentrations were assumed

when the Tyndall beams of the two streams of air appeared to be equal in brightness; the efficiency was then given by the percentage dilution of the original suspension (5). This method was accurate to within 1 per cent. for efficiencies of 98 per cent., but for efficiencies of 25 per cent. or less, errors in individual determinations were as high as 15 per cent. (5, p. 15).

In the present study a Tyndallmeter was employed in which the strength of the Tyndall beam is measured directly by a standard photometer (6). Two methods of determining efficiency were employed: (*a*) In the tests with silica dust and magnesium oxide suspensions (except that produced with the blast lamp) the instrument to be tested was followed by a second impinger in series, and the sampling was continued for a long enough period to allow a visible turbidity to develop in the second flask. Tyndall readings were then obtained for the two suspensions, and the efficiency of collection in the first instrument was calculated from the relationship:

$$E = \frac{T_1}{T_1 + KT_3} \times 100$$

where E = Efficiency in per cent.
T_1 = Tyndall reading of first suspension
T_2 = Tyndall reading of second suspension
K = 1/E (approximately)

This method assumes that the efficiency of collection in the second instrument is equal to that in the first, and also that the relative dust concentrations in the two flasks are given directly by their Tyndall readings. The first assumption is somewhat in error, since it is known that the efficiency of a dust collector of this type varies with concentration; nor is the second strictly true, since the particle size of the material in the second flask is smaller than that in the first and the result is a lower Tyndall reading for a given concentration, owing to the fact that the strength of the Tyndall beam is a function of size as well as of concentration (7). These errors were not large, however, and in one case the value thus determined checked the efficiency obtained by microscopic count within 1 per cent. (94 as compared with 95 per cent.).

(*b*) In the tobacco smoke tests and in the study of the very fine magnesium oxide Tyndall readings were obtained directly on the air suspension before and after passing through a single instrument, and the efficiencies obtained from the relationship:

$$E = \frac{T_1 - T_2}{T_1} \times 100$$

where T_1 = Tyndall reading on original suspension
T_2 = Tyndall reading on discharge from instrument

Since the concentration in the cabinet was continuously decreasing, the value of T_1 was obtained immediately before and after T_2, and the average value used in the foregoing equation.

This method of determining efficiency is similar in principle to that employed by the Bureau of Mines; in both cases it is assumed that the optical properties of the suspension, other than the concentration, are not changed by passing through the impinger. The sensitivity of our Tyndallmeter for high efficiencies is less than that of the instrument used in the earlier investigation, but unlike the latter, its sensitivity increases with

a decrease in efficiency of the apparatus under test.

Test Suspensions

In the investigation of the effect of particle size on the operating characteristics of the impinger, six different suspensions were employed:

1. *Silica dust,* which had been screened through a 200-mesh sieve, was blown up in the cabinet. The dust cloud was allowed to settle about thirty minutes before samples were taken, so that an average particle size of approximately 1.5 microns was obtained. This suspension was similar in nature to that employed in the 1925 study (2, p. 7).

2. *"Wet" tobacco smoke* generated by burning in a combustion chamber ordinary pipe tobacco without previous treatment.

3. *"Dry" tobacco smoke,* obtained by the slow combustion of pipe tobacco previously dried at 80°C. for three hours in a vacuum oven. Air supplied to the combustion chamber was also dried by passing through calcium chloride, and the smoke formed was passed through a good quality filter fabric before entering the cabinet.

The terms "wet" and "dry" smoke are employed here to distinguish between the two methods of generation. In the case of the latter, a smaller particle size and less flocculation were undoubtedly obtained. The smoke produced in both cases probably differed in its dryness and in particle size from that used by the Bureau of Mines, which was produced from sun-dried tobacco leaf, ground, screened, and mixed with a slight amount of potassium nitrate and rosin and then molded and baked on a hot plate (5, p. 12).

4. *Coarse magnesium oxide* obtained by blowing up a cloud of the dried powder.

5. *Medium magnesium oxide* generated by igniting magnesium ribbon and allowing it to burn by itself in the cabinet.

6. *Fine magnesium oxide* made by burning magnesium ribbon in the flame of a blast lamp. The blast of gas caused a continuous scattering of the particles immediately after formation, thus reducing coalescence and resulting in a more stable and more highly dispersed cloud. A smaller particle size was indicated by the blue color of the cloud, as distinguished from the white appearance given by the oxide formed by simple combustion of the magnesium ribbon.

Data and Discussion of Results

The results of our investigation of the operating characteristics of the impinger are discussed under the following headings: (*a*) impinging distance; (*b*) angle of impingement; (*c*) sampling rate; and (*d*) particle size.

Impinging Distance

The distance between the nozzle and the bottom of the flask was varied from 2 to 15 mm. The results given in Table 2 show an increase in efficiency as the impinging distance is decreased, and the change appears to be greater for the material of smaller particle size. Our results with silica dust compare favorably with those reported in 1925 (see p. 303) although the reduction in efficiency was not so great. The results of our tobacco smoke tests, however, are not even comparable. Our efficiencies are much higher (73 to 80 per cent. as compared with 13 to 22 per

cent. for the same conditions of operations) and no indication of an optimum impinging distance is shown.

The wide difference in results is difficult to explain but is probably due to differences in the physical properties of the two smokes employed. (Also, smoke concentrations employed in the earlier study were probably much greater than ours.) This explanation is suggested by the fact that our results with wet and dry smoke show

TABLE 2.—EFFECT OF IMPINGING DISTANCE ON EFFICIENCY OF IMPINGER

(Sampling rate = 28.3 liters per minute)

IMPINGING DISTANCE	EFFICIENCY				
	Silica	Tobacco Smoke		Magnesium Oxide	
		Wet	Dry	Medium	Fine
mm.	%	%	%	%	%
2	98+	88	82	64	55
5	98+	89	81	77	55
7	97	87	80	..	54
10	..	84	75	..	53
12	97	..	..	75	..
13	..	81	73	..	49
15	94	..	..	..	..

significant differences, thus indicating the importance of the nature of the smoke in the operation of the impinger. The value of using tobacco smoke in tests of this character is questioned for two reasons: First, tobacco smoke is by nature a wet material, no matter how it is prepared, and its action in the impinger or any other wet collector therefore bears little relation to that exhibited by solid particulate materials of the same particle size. Second, it is not a standard material in the sense that the size of the particles and its other physical properties are easily duplicated, nor is there any known method for duplicating concentrations on successive tests. Dryness of the tobacco, rate of combustion, and many other factors, influence the nature of the smoke produced.[1]

The data in Table 2 show that no marked change in efficiency occurs when the impinging distance is varied from 2 to 7 mm.; therefore it may be concluded that so far as this factor is concerned, the new impinger may be used with safety in the field, since the impinging distance may be adjusted to a value well within these limits.

TABLE 3.—EFFECT OF VARYING ANGLE OF IMPINGEMENT

(Impinging distance = 5 mm.; sampling rate = 28.3 liters per minute)

ADJUSTMENT OF IMPINGER NOZZLE	EFFICIENCY		
	Silica	Wet Smoke	Magnesium Oxide[1]
	%	%	%
Maximum angle from perpendicular.....	98	87.77[2]	69
Perpendicular.....	98+	89.88[2]	77

[1] Medium size.

[2] At high and low concentrations respectively.

Angle of Impingement

The maximum angular departure of the impinging nozzle from the per-

[1] This point is well illustrated by the difference in appearance of the smoke at the lighted end of a cigar and of that issuing from the opposite end. The blue color of the former indicates a smaller particle size (8).

pendicular occurs when the end of the inlet tube is against the wall of the flask—an inclination of approximately 10 degrees. The efficiency of the instrument with the nozzle in this position is given in Table 3. A comparison with the efficiencies under normal conditions (impinger vertical) shows that the angle of impingement has no serious effect upon the efficiency in the case of silica dust. Against tobacco smoke and magnesium oxide, on the other hand, there is a significant reduction in efficiency. It should be borne in mind, however, that the maximum angular displacement was used in this test; for smaller departures from the perpendicular, the effect is less marked.

Sampling Rate

In the 1925 study, the efficiency of collection was found to increase with the sampling rate, and no optimum value was noted up to 35 liters a minute. Similar results were also found in the present investigation, as shown in Table 4. The data indicate that in the case of the fine materials, an impinging velocity greater than 22,400 feet per minute (developed at 1 cubic foot per minute) should be employed, but the consequent increase in resistance would make the instrument impractical. At 45 liters a minute, for example, the resistance is 7 inches of mercury as compared with 2.9 inches at 28.3 liters.

Since the efficiency against silica dust is close to 100 per cent. at 28.3 liters per minute, there is no advantage in going over this rate.

Particle Size

The impinger was designed as a dust sampling instrument and although its use has been largely confined to the sampling of materials coming within this classification, its advantages as a field instrument have resulted in its use in the sampling of fumes and gases as well.

The original investigation showed a much lower efficiency against tobacco smoke than was obtained with silica dust. As has already been pointed out, however, the action of the impinger on tobacco smoke cannot be compared with the results obtained with silica dust since one is a liquid smoke and the other is made up of discrete solid particles.

TABLE 4.—EFFECT OF SAMPLING RATE ON EFFICIENCY OF IMPINGER

(Impinging distance = 5 mm.)

SAMPLING RATE	EFFICIENCY				
	Silica	Tobacco Smoke		Magnesium Oxide	
		Wet	Dry	Medium	Fine
l./min.		%	%	%	%
15.0	..	57	..	..	15
20.0	91	..	69	..	25
23.0	..	76	..	..	..
25.0	98	..	73	72	38
28.3	98+	90	79	77	55
35.0	98+	93	87	84	62
39.0	..	94	..	..	..
42.5	..	94	..	..	..
45.5	..	95	..	..	..

The effect of particle size on the efficiency of the impinger is better shown by a comparison of the data in Table 5, which give the efficiencies against suspensions of the same material but having different particle sizes. According to these results, the effi-

ciency of collection is proportional to the particle size, and in the case of freshly formed fumes such as magnesium oxide, it becomes so low as to require the use of two instruments in series, if accurate results are to be obtained. In view of these data the indiscriminate use of the impinger for the sampling of fumes and smokes cannot be recommended.

The results given in Table 5 are in accordance with our knowledge of the factors that influence the collection of aerosols by water and other liquids. The phenomena of adsorption, surface tension, electric charges, and the other properties that go to make up the property of wettability, all affect the collecting efficiency and are all undoubtedly associated with particle size.

TABLE 5.—EFFECT OF PARTICLE SIZE ON EFFICIENCY OF COLLECTION OF MAGNESIUM OXIDE BY IMPINGER

(Impinging distance = 5 mm.; sampling rate = 28.3 liters per minute)

METHOD OF CLOUD FORMATION	EFFICIENCY
	%
Chemically precipitated and blown up in cabinet:	
a. Test just after cloud formation	96
b. Test two hours after cloud formation	90
By rapid burning (self-combustion) of magnesium ribbon	78
By burning magnesium ribbon in flame of blast lamp	55

Resistance of Impinger Nozzle and Design of Constant-Flow Meter

The rate of sampling in the field is commonly determined with the aid of a calibrated flowmeter inserted in the suction line from the impinger. Since the calibration depends upon the resistance on the upstream side of the meter, it is impossible to employ the same calibration value for all impinger nozzles unless they have the same pressure loss. The resistance is a function of the nozzle diameter and the condition of its edge, and with the ordinary methods of glass treatment these vary considerably. It has been necessary, therefore, to calibrate the flowmeter for each impinger, obviously an undesirable practice from the standpoint of field operation.

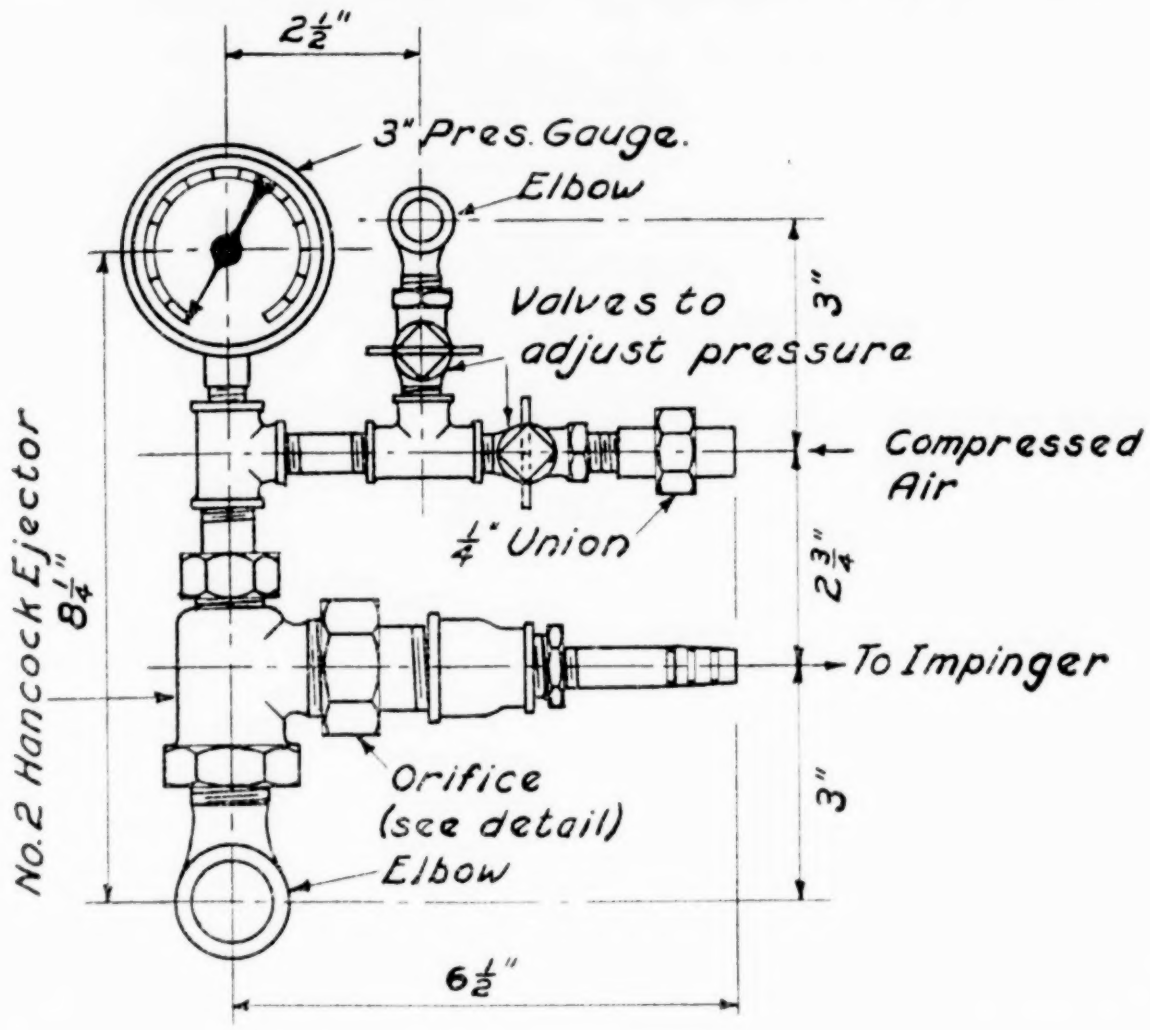
TABLE 6.—RESISTANCE TO AIR FLOW THROUGH IMPINGER NOZZLES REAMED TO DIAMETER TO 2.3 MM

IMPINGER NO.	RATE OF AIR FLOW	PRESSURE LOSS[1]
	l./min.	*in. Hg*
1	29.0	2.77
	29.0	2.80
2	29.2	2.82
	29.0	2.84
3	28.0	2.80
	28.0	2.84
4	29.0	2.84
	29.0	2.83
5	29.0	2.85
	28.0	2.88
	28.6	2.89
	28.6	2.89
Maximum variation	3.5%	4.2%

[1] Pressure loss through nozzle and 11.5 feet of ½-inch I.D. rubber tubing.

In order to eliminate this troublesome factor, the nozzle of the new impinger has been constructed in a manner that can be easily duplicated (see Fig. 1), so that the resistance to

flow has a constant value. In Table 6 we have given the pressure loss just upstream of the flowmeter for a constant rate of air flow (28.3 liters a minute) through five impinger nozzles



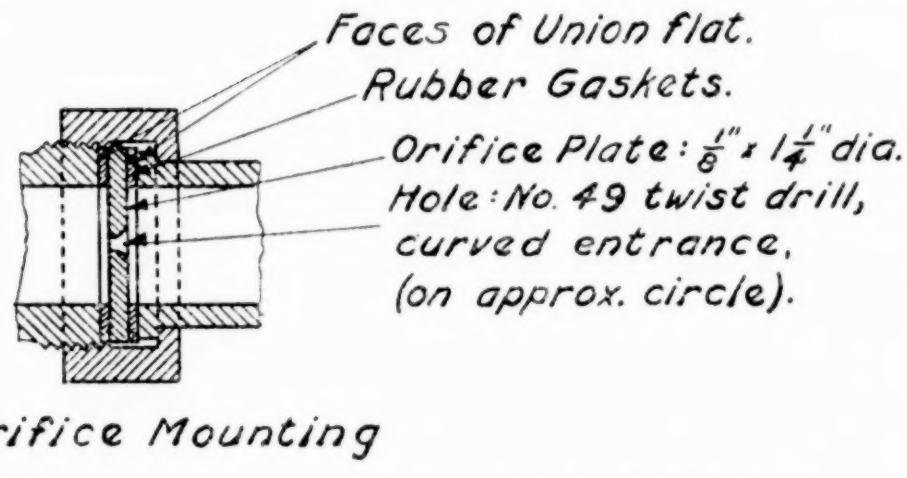

Faces of Union flat.
Rubber Gaskets.
Orifice Plate: ⅛" x 1¼" dia.
Hole: No. 49 twist drill, curved entrance, (on approx. circle).
Orifice Mounting

FIG. 2.—Design of ejector-flowmeter unit and detail of orifice and mounting. Standard fittings used throughout.

to use a flowmeter that will insure a constant rate of sampling without continuous attention and adjustment, even when the power fluctuates. The instrument should have a single constructed according to these specifications. The data show satisfactory uniformity and indicate that instruments of this type can be used interchangeably with the same meter.

In field investigations, it is desirable calibration value for all impingers and should be rugged in construction.

In practically every dusty industry, compressed air is available, and because of the convenience in its application it is commonly used to operate

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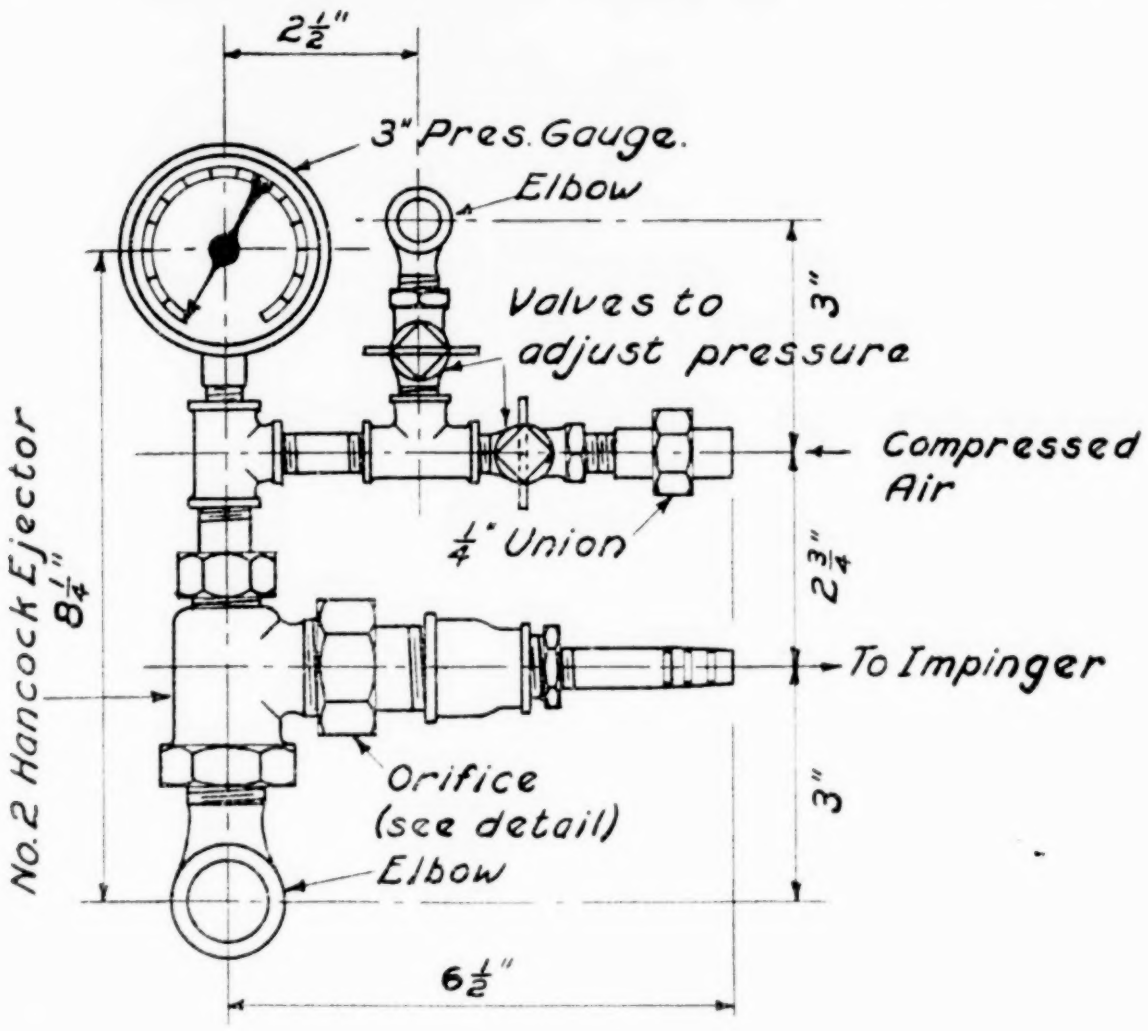

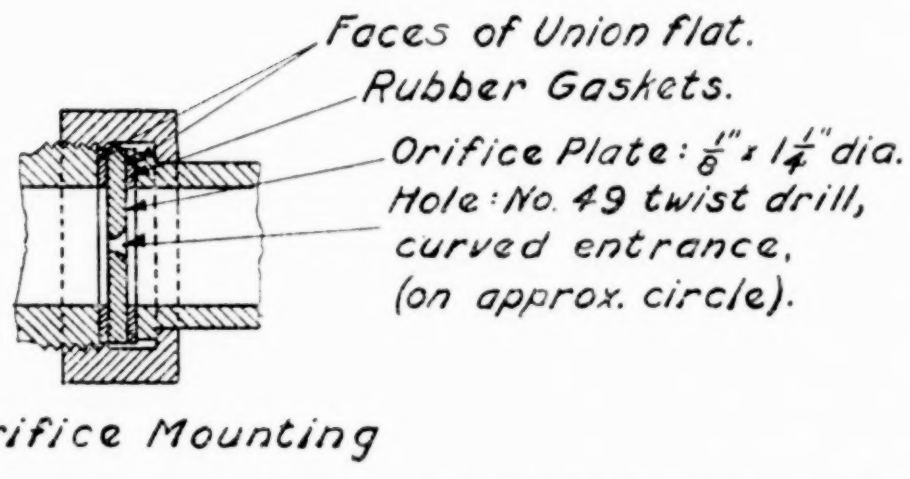

Orifice Mounting

FIG. 2.—Design of ejector-flowmeter unit and detail of orifice and mounting. Standard fittings used throughout.

constructed according to these specifications. The data show satisfactory uniformity and indicate that instruments of this type can be used interchangeably with the same meter.

In field investigations, it is desirable calibration value for all impingers and should be rugged in construction.

In practically every dusty industry, compressed air is available, and because of the convenience in its application it is commonly used to operate

an ejector which furnishes the required suction. A suction device of this type, provided with a flowmeter that appears to meet the foregoing requirements, is shown in Figure 2. It uses about 50 cubic feet per minute of free air in operation and insures a constant rate of flow no matter how much the air pressure fluctuates within the limits of 30 and 75 pounds per square inch. The only indicating device required is an inexpensive pressure gauge connected to the compressed air supply line.

TABLE 7.—RATE OF AIR FLOW THROUGH MODIFIED IMPINGER, RUBBER TUBING, AND A SERIES OF HANDMADE, NOZZLE TYPE ORIFICES[1]

ORIFICE NO.	MAXIMUM FLOW[2]
	l./min.
5	29.0
6	29.0
9	28.3
10	28.75
Maximum variation...	2.5%

[1] See specifications given in Figure 2.

[2] Operating air pressure between 30 and 75 pounds.

The constant flow characteristic of this meter is given for the reason that the pressure drop across the orifice (p_1–p_2) is greater than the critical pressure, 0.53 p for air (9), where p_1 is the upstream, and p_2 the downstream pressure. Under this condition the flow depends upon p_1 alone, and since this remains constant (within the limits of barometric pressure), the rate of air flow has a constant value. Taking the barometric pressure equal to 30 inches of mercury and the pressure loss through the impinger and suction tube equal to 2.9 inches, then p_1 = 27.1 inches. To meet the foregoing requirements, $p_1 - p_2 \geqslant 14.5$ inches ($\geqslant 0.53$ p) and p_2 (absolute) must therefore be less than 12.6 inches Hg, or −17.4 inches mercury gauge pressure. A suction in excess of this value is developed by a No. 2 Hancock ejector when the operating pressure is between 30 and 75 pounds.

In order that the orifice might be easily duplicated, it was constructed with a curved entrance and the burr on the downstream face was carefully removed (checked, by microscopic examination). For a series of five duplicate orifices, the rate of flow was found to be between 28 and 29 liters a minute, with a maximum variation of 3.5 per cent. (see Table 7).

Summary

A modified form of the Greenburg-Smith impinger is described which is more compact and rugged than the standard instrument. The impinging distance is not fixed, but data are presented to show that an approximate adjustment of the instrument insures a collecting efficiency of 96 per cent. or more against silica dusts or similar materials. The instrument employs 75 c.c. of water and volumetric graduations are provided to assist in quantitation.

An investigation of the operation of the impinger in the sampling of materials of smaller particle size shows a marked reduction in the collecting efficiency and suggests that considerable care must be exercised in the widespread use of this instrument for the sampling of fumes and smokes.

An ejector-flowmeter unit which

gives a constant sampling rate so long as the operating air pressure lies within the limits of 30 and 75 pounds per square inch is also described. This instrument is rugged in construction and does not require the use of a delicate and expensive indicating gauge.

BIBLIOGRAPHY

1. Greenburg, L., and Smith, G. W.: A New Instrument for Sampling Aerial Dust. U. S. Bur. Mines, Rep. Investigations, Serial No. 2392, Sept., 1922.
2. Katz, S. H., Smith, G. W., Myers, W. M., Trostel, L. J., Ingels, M., and Greenburg, L.: Comparative Tests of Instruments for Determining Atmospheric Dusts. U. S. Pub. Health Bull. No. 144, 1925.
3. Greenburg, L., and Bloomfield, J. J.: The Impinger Dust Sampling Apparatus as Used by the United States Public Health Service. U. S. Pub. Health Rep., 1932, *47*, 654.
4. Smith, R. B., and Friis, B. S. T.: Portable Motor-Driven Impinger Unit for Determination of Sulphur Dioxide. This Joup., 1931, *13*, 338.
5. Fieldner, A. C., Katz, S. H., and Longfellow, E. S.: The Sugar-Tube Method of Determining Rock Dust in Air. U. S. Bur. Mines, Tech. Paper 278, 1921.
6. Drinker, P., Thomson, R. M., and Finn, J. L.: Photometric Methods for Studying and Estimating Suspensions of Dusts, Fumes and Smokes. Jour. Chem., Metall. and Min. Soc. So. Africa, 1925, *26*, 46.
7. Hatch, T., and Choate, S. P.: Statistical Description of the Size Properties of Non-Uniform Particulate Substances. Jour. Franklin Inst., 1929, *207*, 369.
8. Gibbs, W. E.: Clouds and Smokes. The Properties of Disperse Systems in Gases and their Practical Applications. Philadelphia, P. Blakiston's Son & Co., 1924.
9. Mapks, L. S.: Mechanical Engineers' Handbook. Third edition. New York, McGraw-Hill Book Co., 1930.

BOOK REVIEWS

ALLEN'S COMMERCIAL ORGANIC ANALYSIS. A Treatise on the Properties, Modes of Analysis, and Proximate Analytical Examination of the Various Organic Chemicals and Products Employed in the Arts, Manufactures, Medicine, Etc., with Concise Methods for the Detection of their Impurities, Adulterations, and Products of Decomposition. Volume IX. The Proteins of Plants, the Proteins of Milk, Milk, Milk Products, Meat and Meat Products. By *C. Ainsworth Mitchell*, M.A., D.Sc., F.I.C., and D. Jordan Lloyd, G. D. Elsdon, H. Leffmann, J. Golding, E. R. Bolton, and C. R. Moulton. Fifth edition. Cloth. Pp. ix, 617 with index and illustrations. Philadelphia: P. Blakiston's Son & Co., Inc., 1932.

Allen's "Commercial Organic Analysis" is so well known that a general description would seem unnecessary. There are several features of Volume 9 of the new edition, however, that merit attention. Generous space, for instance, is devoted to milk and meat and their products. Thus, the principal sections into which the book is divided are: proteins of plants, 34 pages; proteins of milk, 31 pages; milk, 30 pages; milk products, 112 pages; and meat and meat products, 388 pages.

While careful attention is devoted to description and definition of the various foods comprised under these headings, the bulk of the book obviously is given over to description of methods of analysis. These represent the best present day analytic practice; the instructions are detailed so that reference to the literature is unnecessary, and instead of limiting a given determination arbitrarily to one method, a choice of methods is usually presented.

The presence (accidental or otherwise) of metals in foods is noted—particularly tin and antimony in foil-wrapped cheese, various metals in canned foods, lead chromate, lead dust, zinc sulphate and copper salts in cheeses, and arsenic in fish—and several methods for the detection and estimation of these objectionable substances are given.

The sections on food spoilage, poisonous meats, ptomaine poisoning, the applications of bacteriology and the use of precipitin reactions in the detection of horse meat or other substitutes are of especial interest to students of public health.

Public health regulations and the detection of artificial color, preservatives and unsound food materials—especially meats—receive generous treatment. In addition to constant reference to the current literature in the text, a bibliography follows each section.—*Lawrence T. Fairhall.*

THE BRITISH SYSTEM OF SOCIAL INSURANCE. By *Percy Cohen*. With an Introduction by the Rt. Hon. Neville Chamberlain, M.P. Cloth. Pp. 278 with index. New York: Columbia University Press, 1932.

This is a reliable book of reference for the social worker and politician interested in the historical background and present status of the various plans of social insurance adopted by the British government. The rights and obligations of all the parties to the plans are explained in detail, as are the legislative steps incidental to the plans

of health insurance, various pension plans, unemployment insurance, workmen's compensation, and industrial assurance.

The author confines this volume to the historical and legislative problems and gives no consideration to the economic successes or failures of the schemes. Considerations of these appear to be of more vital importance than other subject matter.—*Charles F. Horan.*

ACCIDENTS, NEUROSES AND COMPENSATION. By *James H. Huddleson*, M.D., Associate in Neurology, Columbia University; Attending Neurologist, Neurological Institute, New York. With a Foreword by J. Ramsay Hunt, M.D., Sc.D., Professor of Neurology, Columbia University. Cloth. Pp. ix, 256 with index. Baltimore: Williams & Wilkins Co., 1932.

The constantly increasing cost of workmen's compensation benefits, together with the present day legislative and judicial tendency to consider disabilities of many sorts as proper charges against industry makes the consideration of nervous disorders an important one by the physicians and industrial relations managers. The problems are of immediate importance from the economic and social viewpoint as well as from the medical.

The publishers state "Dr. Huddleson herein presents a succinct, straightforward review of the many problems which surround the nervous disorders that are, or alleged to be, the result of accident and hence compensable under the workmen's compensation laws." Especial emphasis is laid on the psychic aspects and the relation to compensation.

The book is written in an extremely broad manner; the literature in relation to traumatic neuroses is reviewed in an extensive and interesting way, and should be of considerable value to all persons in industry and in law who are concerned with accident cases. We know of no other work along these lines which has covered the problems so thoroughly from all viewpoints.

The author accepts the psychic origin of traumatic neuroses, and discards the theory of molecular changes in the central nervous system following injury. The three theories of psychopathologic mechanisms are reduced to: Freud's theory of "sex-life in the past," Jung's "satisfaction in the present," and Alder's "goal attainment." Historically, the author reviews traumatic neuroses of the World War in: "Reward and punishment as curative principles have variously supplemented and replaced each other in the history of traumatic neuropsychiatry. Neglect and misunderstanding were met before the World War; the death penalty for a very brief war time period; then coddling, hero-worship, and unmilitary comforts to some, contemporaneously with torpillage and intensive re-education for others. Finally, strong protests in Germany and France, not yet echoed in England and America, have arisen against the payment of insurance or other reward for any neuroses."

Traumatic neuroses are rare in youth, and whether there are clearly defined sex differences in liability to neuroses following injury is an open question, although more malingering of the type of conscious exaggeration of genuine symptoms seems ascribable to women than to men under the modern conditions of insurance. The physical type most prone to neuroses are persons tall, slender and inclined to lum-

bar lordosis, with long, narrow cylindrical thorax, and slenderness in the long bones. A physical make-up inferior at any point unquestionably predisposes to the development of neuroses. Exhaustion and overexertion "must not be thought of as all-important" for traumatic neuroses. Overwork is less a predisposing cause of traumatic than of occupational mental ills. Development defects in the form of mental deficiency are thought to be protective, rather than causative. Malnutrition has been considered a predisposing factor, although the neuroses may be responsible for the ill-nourished state. While there is little evidence that alcoholics are more prone to neuroses than total abstainers, the condition is more difficult in treatment and eradication in the chronic alcoholic. Exhaust gases from combustion engines as a cause of nervous symptoms have come under suspicious scrutiny recently. The author, following the belief of Collie, comments favorably on the attitude of the German courts that the truly traumatic effect of accidents on the nervous system should be proportionate to the nature of the accident.

While some investigators have noted a high incidence of neuroses and neurasthenia in the so-called needle (clothing manufacturing) trades, and have believed that this condition has been influenced by the racial tendencies, the writer takes no position in this many-sided controversy. He believes that racial facts are difficult or impossible to determine because of racial, political, and religious prejudices and jealousies; and believes that the stigma of furnishing large numbers of the neurologic class should not be placed on any racial group. A better division, he believes, is on the basis of intelligence.

Social custom and public opinion tend to encourage the development of traumatic neuroses by the present attitude toward the question of responsibility. The grocer's boy may drive the employer's truck as recklessly as he pleases, but let an accident occur and the responsibility is immediately shifted from the grocery boy to the employer. There is a noted growing feeling among all classes that responsibility can always be shifted from the individuals directly involved to some higher authority. The result has been that the recovery from a neuroses, instead of being the business of the person who exhibits it, and for whose temporary benefit it has been evolved, becomes the business of persons who have no better approach than by financial payments. The greater the social tendency to shift responsibility the more frequent and more refractory do mental illnesses following injury become. In industry the malingerer is fairly safe, having everything to gain and practically nothing to lose; while he may not succeed in obtaining financial redress, the point is that he goes unpunished—and therein lies an incentive to exaggeration. Under military conditions the fear of punishment is a strong preventive force. Severe wounds appear to be negative or prophylactic factors, as employees who suffer these injuries already have a compensable disability, and in such cases the wound itself affords an escape with honor from an unbearable situation that the neuroses similarly accomplishes.

The latent period between the trauma and the development of ner-

vous symptoms does not correspond to any degenerative process, but appears to depend upon exposure to suggestions upon the part of friends and others—or to autosuggestion upon the part of the patient. The attending physician and the representative of the employer or insurer are frequently the cause of the neuroses by failure to handle the patient properly in the first several weeks of disability.

Classification and symptomatology, structural pathology, duration and prognosis, and differential diagnosis are considered in detail by the author. The matter of treatment and both the medical and economic aspects of early treatment are covered in an extensive manner.

The chapter on "Compensation" contains very pointed discussions on workmen's compensation laws as factors in the evolution of traumatic neuroses. The compensation principle should be designed for the rehabilitation of the injured worker rather than as punishment of the employer. The author suggests that the payment of regular weekly compensation in cases of neuroses "is as far from curative as a beer diet in obesity." He believes that the awards of money should be given in a single sum at the earliest possible time, and that the sums should range from fifty to five hundred dollars. The postponement of cash awards destroy their curative value. In Denmark the practice is to pay injured employees lump sum settlements at a very early stage of their disability, and, in consequence 93.6 per cent. recover from traumatic neurasthenia. In Germany the disabled worker is entitled to a pension, and but 9.3 per cent. recover from the same condition. The return of the injured employee to his old occupation as against cash settlement sufficient to "buy a business" is advocated by the author.—*Charles F. Horan.*

WORKERS' EMOTIONS IN SHOP AND HOME. A Study of Individual Workers from the Psychological and Physiological Standpoint. Research Study No. XVIII, Industrial Research Department, Wharton School of Finance and Commerce, University of Pennsylvania. By *Rexford B. Hersey*, Research Associate and Assistant Professor of Industry. Cloth. Pp. xviii, 441 with index. Philadelphia: University of Pennsylvania Press, 1932.

This is a rare and valuable book. The direct observation of the worker on his job and in his home life has been attempted often enough by observers who have tried to put themselves in the worker's place, to ape his manners, and to imitate his mode of living. Uusually, however, the result has been an unhappy concoction of much sentiment and little science. Professor Hersey has boldly acknowledged his purpose to his subjects and with rare tact and unusual intuition has elicited from his observations a series of case studies whose authenticity is patent to anyone who has ever lived with or worked with the ordinary wage-earner.

Among the individual cases he deals with the contented man, with youth and its problems, with the worker of low I.Q., with the effects of an unhappy home life, with the spectre of unemployment, with the reaction to a monotonous job in a severe emotional crisis, with the relative effects of the foreman's methods, and with other reagents.

One section of the book deals with

happiness and work: the reaction of the emotions on productivity, and the relation between zest for activity and physical condition. In the chapter on fatigue the author discusses the high mental factor in industrial fatigue. A chapter on recurrent emotional fluctuations indicates how analyses of the records of several of the workers supply definite evidence of a fairly regular, if not actually rhythmic, fluctuation in the emotional resistance of the workers. It was seen that at certain times a job would be going poorly, yet the worker would laugh the situation off with little emotional tension. A few weeks later, with sleep, weather conditions, home relationships, and all other circumstances practically the same, so far as one could tell, failure to do a job well would greatly depress the worker. For each worker the length of this period is quite constant. The author's study of these high and low periods have a value for all of us. For the brain-worker he finds encouragement even in the "lows." "It is doubtful in my mind," he says, "if any man who never experiences low moods can produce great things in the world no matter what his capacity."

The author's analysis of the financial problem and the family is acute. The desire to "keep up with the Jones" he finds to be "merely another illustration of the abnormal way in which Americans satisfy their craving for individual expression through a warped application of the gregarious instinct."

He reminds us too, that in spite of his fluctuation between high and low emotional phases, man is by nature more constant and dependable than the joint systems of production and distribution which he operates. Nevertheless some provision should be made for variations in the amount of output, if not in the nature of the work. Above all others, he cautions, the executive must recognize his own liability to the variations between these high and low states and take every possible step to safeguard himself and his capacity for realistic thinking during both periods. He reminds all of us that when life is at its worst and both work and play have lost their zest and we are simply ready to offend everyone, 80 per cent. of the time the only cause for such blackness really lies inside ourselves.

If, even in these dark moments the realization can be brought home to us that on the other side lies a change in mood, our time of depression will, even if we cannot eliminate it, be freed of much of its affliction. Such thoughts, that one is tempted to quote or to paraphrase too extensively, form the author's contribution to a philosophy of living.

Whether one wishes more to know others or to understand himself, this book contains much to help one in the search.—*C. P. Flora.*